Species Report of *Ochrosia haleakalae* (hōlei)
Version 1.0

*Ochrosia haleakalae* flower, Hawai‘i Volcanoes National Park (Photo credit: Alan Cressler)

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## EXECUTIVE SUMMARY

*Ochrosia haleakalae* (hōlei) is a small tree in the dogbane family (Apocynaceae) endemic to islands of Maui and Hawaiʻi in the Hawaiian archipelago (Wagner et al. 1999, p. 218. This species is known to occur in the dry grasslands and shrublands (Maui), mesic grasslands and shrublands habitat (Maui and Hawaiʻi), wet grasslands and shrublands (Hawaiʻi), mesic forest (Maui and Hawaiʻi), and wet forest (Maui and Hawaiʻi) habitats (U.S. Fish and Wildlife Service (USFWS) 2020, unpublished data). This species can tolerate relatively wide ranges of precipitation and elevation.

Factors influencing the viability of this species include habitat loss and modification by nonnative plants and animals, herbivory by nonnative animals; wildfire (primarily caused by humans); hurricanes; inadequate regulatory mechanism, and low regeneration in wild for some of the populations. Additionally, we anticipate that climate change will exacerbate these factors (e.g., wildfires and hurricanes). Inadequate regulatory mechanisms also influence the viability of this species, primarily regarding biosecurity. Only some of the populations of *Ochrosia haleakalae*, or portions thereof, are within fenced exclosures that protect the species from one or more of the nonnative animals. Ongoing conservation actions that are known to benefit *O. haleakalae* are implemented at some but not all of the population sites. Several of the smallest populations receive little to no conservation actions and may no longer be extant.

There are 16 records (six on Maui and ten on Hawaiʻi) of *Ochrosia haleakalae* from the last 100 years, 12 of which are wild populations (six on Maui and six on Hawai'i). Of the four outplanted populations on Hawaiʻi, three are introduced populations, and one is a reintroduction. There is also one additional population, Laupāhoehoe population D, that is extirpated, but then propagated individuals were outplanted at the same site, so this population is recorded as both wild and reintroduced. The largest wild population, both historically and presently, now estiamted at 250 to 350 individuals, is located in the Auwahi ahupuaʻa on the island of Maui. This population has natural recruitment and regeneration (Oppenheimer 2020, in litt.).

Additionally, there are numerous outplanted individuals (over 1,300 individuals) among the wild Auwahi population, which also experience natural regeneration. The second largest population, which is substantially smaller, consists of between 13 and 32 individuals in the Makawao ahupuaʻa, which is also on the island of Maui. The Makawao population experiences natural recruitment Oppenheimer 2020, in litt.). The island of Hawaiʻi hosts only very small (fewer than 15 individuals each, most with less than 5 individuals each) wild populations; however, there are two large introduced sites totaling approximately 250 individuals within Hawaiʻi Volcano National Park, both with natural recruitment and regeneration. Recently, 41 individuals were introduced at a third site within the park. Although these three outplanted populations are planted within habitat types known to support *O. haleakalae*, these three populations expand the known range for this species. *Ochrosia haleakalae* was selected for outplanting within Hawaiʻi Volcano NP as a surrogate for the now extinct *O. kilaueaensis* (HAVO 2019, p. 20). The remaining populations of *O. haleakalae* are very small, the largest of which has only 13 individuals. Several of these populations have not been observed for a decade or more so there status is unknown. At least two are thought to be extirpated.

With the exception of the one large reproducing population in Auwahi on Maui, and despite natural regeneration at Makawao and at two of the three introduced sites within Hawai‘i Volcano NP, all of the remaining *Ochrosia haleakalae* populations are small and vulnerable to stochastic events, or believed to be extirpated. Even though the number of outplanted individuals within Hawai‘i Volcano NP is approximately 250, we only consider the naturally recruited individuals that made it to adulthood in our evaluation of resiliency. Therefore, we assess the cumulative resiliency for the species under current condition as very low. *Ochrosia haleakalae* has multiple small populations spread out across the species range, in various habitat types, and the range of the species has expanded, we therefore assessed the species redundancy under current condition to be low to moderate. With only one large healthy population, the species remains at risk of catastrophic events. Considering the resiliency and redundancy of the species, in addition to the diminished genetic and environmental diversity of the species, we assess the representation of this species under current condition as low. Therefore, our assessment of the viability of *O. haleakalae* under current condition is low.

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## INTRODUCTION

*Ochrosia haleakalae* (hōlei) is a small tree in the dogbane family (Apocynaceae) endemic to islands of Maui and Hawaiʻi in the Hawaiian archipelago (Wagner et al. 1999, p. 218. This species currently occurs in the dry grasslands and shrublands (Maui) (which is degraded dry forest habitat), mesic grasslands and shrublands habitat (Maui and Hawaiʻi; likely degraded mesic forest on Maui), wet grasslands and shrublands (Hawaiʻi), mesic forest (Maui and Hawaiʻi), and wet forest (Maui and Hawaiʻi) habitats (U.S. Fish and Wildlife Service (USFWS) 2020, unpublished data). This species can tolerate relatively wide ranges of precipitation and elevation. The largest wild population, and overall number of wild individuals, occur on east Maui.

### Species Report Overview

This Species Report summarizes the biology and current status of *Ochrosia haleakalae* (hōlei) and was conducted by Pacific Islands Fish and Wildlife Office. It is a biological report that provides an in-depth review of the species' biology, factors influencing viability (threats and conservation actions), and an evaluation of its current status and viability.

The intent is for the Species Report to be easily updated as new information becomes available, and to support the functions of the Service's Endangered Species Program. As such, the Species Report will be a living document and biological foundation for other documents such as recovery plans, status in biological opinions, and 5-year reviews.

### Regulatory History

*Ochrosia haleakalae* was proposed for listing as an endangered species in 2015 (U.S. Fish and Wildlife Service (USFWS) 2015, entire). In 2016, hōlei was added to the Federal List of Endangered and Threatened Plants (50 CFR 17.12) as an endangered species (USFWS 2016a, entire). There is currently no designated critical habitat for this species.

### Methodology

We used the best scientific and commercial data available to us, including peer-reviewed literature, grey literature (government and academic), and expert elicitation. Because little information is available about *Ochrosia haleakalae*, we gathered information on congeneric species within *Ochrosia*, in conjunction with basic flowering plant biology and known information about the habitats in which *O. haleakalae* is known to occur, to fill in data gaps. For example, we looked at abiotic features of habitat types across the range *O. haleakalae* to hypothesize the species basic needs. Further details regarding our methods of assessing resiliency, redundancy, and representation are provided throughout this report.

To assess the current status and viability of *Ochrosia haleakalae*, we identified population units. The classic definition of a population is a self-reproducing group of conspecific individuals that occupies a defined area over a span of evolutionary time, an assemblage of genes (the gene pool) of its own, and has its own ecological niche. However, due to information gaps, we could not assess the viability of *O. haleakalae* using this definition. The Hawaiʻi and Pacific Plants Recovery Coordinating Committee revised its recovery objectives guidelines in 2011 and included a working definition of a population for plants: "a group of conspecific individuals that are in close spatial proximity to each other (i.e., less than 1,000 meters apart), and are presumed to be genetically similar and capable of sexual (recombinant) reproduction" (HPPRCC 2011, p. 1).

Based on this working definition, maps were created to display population units. In an effort to protect the sensitivity of species data, we created maps with symbol markers rather than displaying species points or polygons. We created the symbols in steps. First, we added a 500-meter buffer around each individual species point and polygon. We then dissolved all buffer areas intersecting each other into a single shape. Next, we created a centroid (i.e., point representing the center of a polygon) within each dissolved buffer area. The symbol marker represents the centroid. Finally, the Disperse Marker tool in ArcGIS Pro was used shift symbol markers that were overlapping so they would all be visible at the scale of the map. All points and polygons were used in this process, regardless of observation date or current status (historical, current, extant, or extirpated), to represent the known range of the species.

**Species Viability**

The Species Report assesses the ability of *Ochrosia haleakalae* to maintain viability over time. Viability is the ability or likelihood of the species to maintain populations over time, i.e., likelihood of avoiding extinction. To assess the viability of *O. haleakalae*, we used the three conservation biology principles of resiliency, redundancy, and representation, or the "3Rs" (Figure 1; USFWS 2016b, entire). We will evaluate the viability of a species by describing what the species needs to be resilient, redundant, and represented, and compare that to the status of the species based on the most recent information available to us.

**Definitions**

**Resiliency** is the capacity of a population or a species to withstand the more extreme limits of normal year-to-year variation in environmental conditions such as temperature and rainfall extremes, and unpredictable but seasonally frequent perturbations such as fire, flooding, and storms (i.e., environmental stochasticity). Quantitative information on the resiliency of a population or species is often unavailable. However, in the most general sense, a population or species that can be found within a known area over an extended period of time (e.g., seasons or years) is likely to be resilient to current environmental stochasticity. If quantitative information is available, a resilient population or species will show enough reproduction and recruitment to maintain or increase the numbers of individuals in the population or species, and possibly expand the range of occupancy. Thus, resiliency is positively related to population size and growth rate, and may influence the connectivity among populations.

**Redundancy** is having more than one resilient population distributed across the landscape, thereby minimizing the risk of extinction of the species. To be effective at achieving redundancy, the distribution of redundant populations across the geographic range should exceed the area of impact of a catastrophic event that would otherwise overwhelm the resilient capacity of the populations of a species. In the report, catastrophic events are distinguished from environmental stochasticity in that they are relatively unpredictable and infrequent events that exceed the more extreme limits of normal year-to-year variation in environmental conditions (i.e., environmental stochasticity), and thus expose populations or species to an elevated extinction risk within the area of impact of the catastrophic event. Redundancy is conferred upon a species when the geographic range of the species exceeds the area of impact of any anticipated catastrophic event.

In general, a wider range of habitat types, a greater geographic distribution, and connectivity across the geographic range will increase the redundancy of a species and its ability to survive a catastrophic event.

**Representation** is having more than one population of a species occupying the full range of habitat types used by the species. Alternatively, representation can be viewed as maintaining the breadth of genetic diversity within and among populations, in order to allow the species to adapt to changing environmental conditions over time. The diversity of habitat types, or the breadth of the genetic diversity of a species, is strongly influenced by the current and historic biogeographical range of the species. Conserving this range should take into account historic latitudinal and longitudinal ranges, elevation gradients, climatic gradients, soil types, habitat types, seasonal condition, etc. Connectivity among populations and habitats is also an important consideration in evaluating representation.

The viability of a species is derived from the combined effects of the 3Rs. A species is considered viable when there are a sufficient number of self-sustaining populations (resiliency) distributed over a large enough area across the range of the species (redundancy) and occupying a range of habitats to maintain environmental and genetic diversity (representation) to allow the species to persist indefinitely when faced with annual environmental stochasticity and infrequent catastrophic events. Common ecological features are part of each of the 3Rs. This is especially true of connectivity among habitats across the range of the species. Connectivity sustains dispersal of individuals, which in turn greatly affects genetic diversity within and among populations. Connectivity also sustains access to the full range of habitats normally used by the species, and is essential for re-establishing occupancy of habitats following severe environmental stochasticity or catastrophic events (see Figure 1 for more examples of overlap among the 3Rs). Another way the three principles are inter-related is through the foundation of population resiliency. Resiliency is assessed at the population level, while redundancy and representation are assessed at the species level. Resilient populations are the necessary foundation needed to attain sustained or increasing representation and redundancy within the species. For example, a species cannot have high redundancy if the populations have low resiliency. The assessment of viability is not binary, in which a species is either viable or not, but rather on a continual scale of degrees of viability, from low to high. The health, number and distribution of populations were analyzed to determine the 3Rs and viability. In broad terms, the more resilient, represented, and redundant a species is, the more viable the species is. The current understanding of factors, including threats and conservation actions, will influence how the 3Rs and viability are interpreted for *Ochrosia haleakalae.*

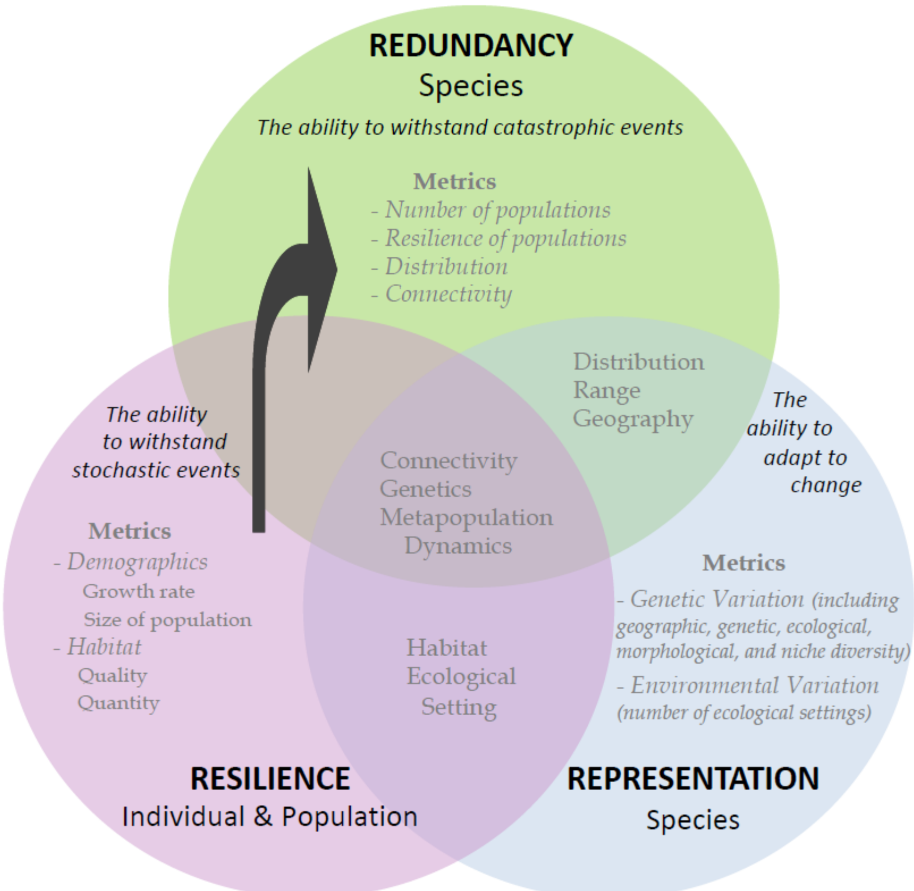


Figure 1. The three conservation biology principles of resiliency, redundancy, and representation, or the "3Rs".

## SPECIES NEEDS/ECOLOGY

### Species Description

*Ochrosia haleakalae* (hōlei) is a small tree in the dogbane family (Apocynaceae) endemic to islands of Maui and Hawaiʻi in the Hawaiian archipelago (Figure 2). There are approximately 40 species within the monophyletic genus *Ochrosia* spanning from Madagascar and eastward through Australia and Polynesia (Kondo and Kondo 2007, pp. 127, 130–131). Four of these approximately 40 species are endemic to the Hawaiian Archipelago, including *O. kilaueaensis*, *O. kauaiensis*, *O. haleakalae*, and *O. compta* (Wagner et al. 1999, pp. 216–19). *Ochrosia* is thought to have arrived in the Hawaiian Archipelago by long-distance water dispersal from

Australasian, made possible by its fleshy, buoyant fruits (Simões et al. 2016, p. 99). *Ochrosia kilaueaensis*, endemic to the island of Hawai‘i, is believed to be extinct. Earlier (1826–1888) taxonomic studies of *Ochrosia* in the Hawaiian Islands proposed just one endemic species, *O. sandwicensis*, in the islands, which persisted for over 50 years until 1888 when Hillebrand described *O. compta*, collected from Nu‘uanu Valley on O‘ahu. Shortly after, *O. sandwicensis* was synonymized with *O. compta*. This classification persisted until 1978. In 1978, St. John (pp. 199–220) conducted a complete taxonomic review of Hawaiian *Ochrosia* resulting in the recognition of 11 single-island endemic species in the islands. Wagner et al.’s (1999, pp. 216–218) re-evaluation and reduction (synonymizing) of the number (11 to 4) of endemic Hawaiian *Ochrosia* species resulted in *O. hamakuaensis* becoming a synonym of *O. haleakalae*. Similarly, many early references of *O. sandwicensis* actually refer to *O. haleakalae* due to *O. haleakalae* being the most abundant of the Hawaiian *Ochrosia* since the historic record (Herbaria Pacificum 2020; USFWS 2020, unpublished data).

*Ochrosia haleakalae* trees are between approximately 7 to 26 feet (ft) (2 and 8 meters [m]) tall (Figures 3e and 3f) and have smooth, deep green, simple, entire, elliptical leaves with a yellowish midrib and conspicuous secondary venation, with three to four leaves per node (Figures 3a and 3d). Characteristic of all species within Apocynaceae, *O. haleakalae* produces a milky sap (latex). Flowers are perfect, fragrant, and pale greenish-white with five petals (Figures 3a). The floral fragrance is similar to that of plumeria flowers. Inflorescences are in compound cymes arising in the leaf axils near the terminal ends of branches, often only one flower opens per day subtended by small, opposite, ovate bracts. When flowers are open, the petals curl slightly backward. Stamens are inserted on the corolla tube just below the mouth of the flower. Flowers of *O. haleakalae* have two ovaries which give rise to two adjacent drupaceous (succulent fruit with a single seed enclosed by a stony layer in the fruit wall (i.e., endocarp) (e.g., peaches and olives)) fruits that are ovoid (oval) to lanceoloid-ellipsoid (broadest near the base and somewhat concavely attenuate to the apex (tapered to a point) (Figures 3b and 3c). Ripe fruits are yellow or plum-colored streaked with brown and approximately 1.6 to 2.4 in (4 to 6 cm) long and 1.1 to 1.4 in (2.8 to 3.6 cm) wide. Fruits develop irregular ridges at maturity due to differential thickening of the exocarp (Wagner et al. 1999, pp. 216–219).

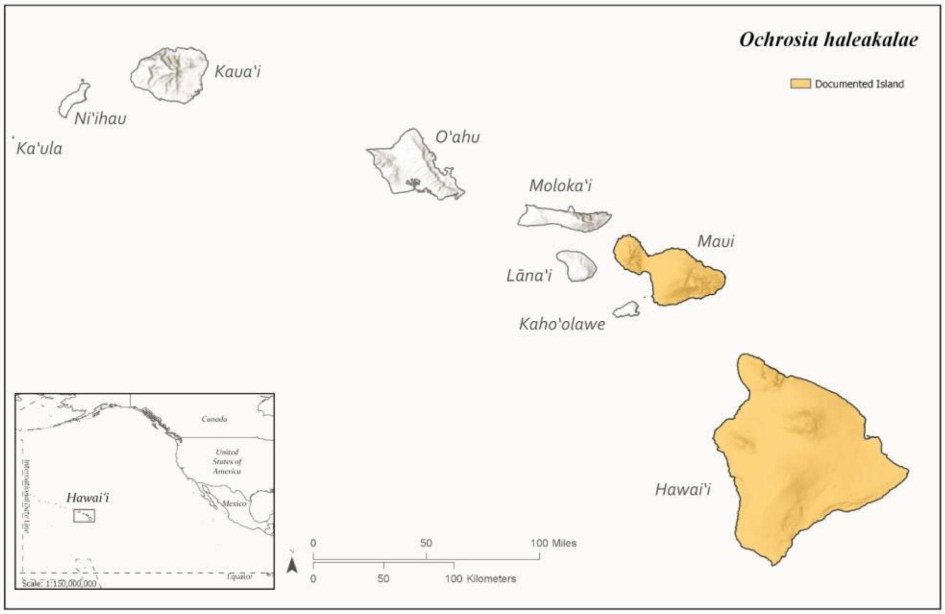


Figure 2. Map of Hawaiian Archipelago and range of *Ochrosia haleakalae*.

(3a) Flower

(3b) Fruit (yellow and green)

(3c) Fruit (purple-ish) (3d) Leaves (note yellowish midrib)

(3e) Medium size tree (3f) Large size tree

Figure 3. *Ochrosia haleakalae* flowers, fruit, leaves, and growth habit (Photo credit: all photos by Kim and Forest Starr).

According to the cumulative data, the habitats in which wild *Ochrosia haleakalae* populations are known to occur currently include dry grasslands and shrublands (Maui; degraded former dry forest), mesic grasslands and shrublands (Maui (likely degraded mesic forest) and Hawai‘i), wet grasslands and shrublands (Hawai‘i), mesic forest (Maui and Hawai‘i), and wet forest (Maui and Hawai‘i), and, from approximately 1,316 to 4,006 ft (401 to 1,220 m)) (Service 2016a, p. 67,801; Service 2020, unpublished data). This elevation range is slightly broader than what is documented throughout most of the literature (i.e., 2,300 to 4,000 ft (700 to 1,200 m)–which is based largely on Wagner et al. (1999, p. 218); however, the more broad range included in this species report reflects the cumulative data to date regarding known locations of *O. haleakalae*. According to the Manual of the Flowering plants of Hawai‘i, *O. haleakalae* occurs in the dry to mesic forest habitats (Wagner et al. 1999, p. 218). Our habitat types deviate from the manual as we used the habitat classifications described in our Habitat Status Assessments to describe current habitat types in conjunction with the collective observations for the species to date, including all of the herbarium specimens housed at the Bishop Museum's Herbarium Pacificum (BISH).

Dry grasslands and shrublands habitat in the Hawaiian Archipelago is defined as having grasses and shrubs between 3.3 and 10 ft (1 and 3 m) in height, annual precipitation ranging from 4 to 69 inches (in) (100 and 1,750 centimeters [cm]), and occurs between elevations ranging from 50 and 11,100 ft (Pe'a et al. 2020, p. 2). Mesic grasslands and shrublands habitat is defined as being dominated by shrubs and grasses between 3.3 and 10 ft (1 and 3 m) in height, with an annual precipitation range from 1,200 to 2,500 millimeters (mm) per year and occurs between elevation ranging from 30 to 2,300 m (Ball et al. 2020, p. 2). Wet grasslands and shrublands habitat is dominated by shrubs and grasses between 3.3 and 10 ft (1 and 3 m) in height, annual precipitation range from 30 to 98 in (750 to 2,500 mm), and occurs between elevations ranging from 1,000 to 7,545 ft (300 to 2,300 m) (NatureServe 2020; Nelson et al. 2020, entire; USGS 2020, in litt.). Mesic forest is defined as having a moderate amount of moisture (neither dry nor wet) with greater than 25 percent forest cover, annual precipitation ranging from approximately 47 to 98 in (1,200 to 2,500 mm), and occurs between elevations ranging from 98 and 6,561 ft (30 and 2,000 m). Wet forest habitat is primarily defined as having more than 98 in (2,500 mm) annual precipitation, greater than 25 percent tree cover, and can occur from 328 to 7,218 ft (100 to 2,200 m) elevation (Clark et al. 2020, p. 2). The diversity of habitat types and associated broad elevations ranges are largely a result of the unique physical geography of the Hawaiian Archipelago (Harrington et al. 2020, entire). For further information regarding the habitat types in which populations of *O. haleakalae* are known to occur, including associated species, please refer to Individual Needs, as well as the detailed habitat status assessments conducted by Ball et al. (2020, entire); Clark et al. (2020, entire); Lowe et al. (2020, entire); Nelson et al. (2020, entire); and Pe'a et al. (2020, entire) (see Table 1).

*Ochrosia haleakalae* trees are an important component in Hawaiian traditional ecological knowledge as the fragrant flowers can be used in lei (Wianecki 2018, in litt.; Native Plants Hawai'i 2020), the wood used for mo'o (gunwales) on canoes, and various parts of the tree for a variety of other purposes (e.g., medicine, food, dye for kapa (tapa) cloth) (Krauss 1993, pp. 50, 65 cited in Native Plants Hawai'i 2020; Medeiros et al. 1998, p. 25; Native Plants Hawai'i 2020).

**Individual Needs**

There are no studies pertaining to the life history needs of *Ochrosia haleakalae*; however, by looking at the habitats in which it is known to occur alongside what we know from propagation experts, about the genus *Ochrosia*, and about basic angiosperm (flowering plants) biology, we can make some assumptions or hypotheses regarding basic requirements such as water, light, soil, nutrient needs, space, and life stages. Similarly as with *O. haleakalae*, there is a paucity of information for the genus as well, but we include the available relevant information here.

Based on what we know about angiosperms, we can assume the life cycle of *Ochrosia haleakalae* includes seeds that become seedlings, then become vegetative plants, and then flowering plants. Flowers of *O. haleakalae* bloom in the late summer and fall (Native Plants Hawai'i 2020). Several rare plant nurseries have successfully propagated seeds of *O. haleakalae*, which contribute towards augmentation of several existing populations and the introduction at several new sites resulting in an expansion in range for the species (see Conservation Actions and Current Condition). Germination rates during early seed propagation efforts for *O. sandwicensis* (which included *O. haleakalae* until 1978) were reportedly 5 to 30 percent (Obata 1967, p. 15). Recent germination rates for *O. haleakalae* remain low and the species is notoriously difficult to propagate (Quintana 2020, in litt.). The rare plant facility at Olinda on Maui has had the most success. Their pretreatment protocol includes allowing the fruit tissue to decompose around the seed, after which the seed is blasted clean with a jet of water (Quintana 2020, in litt.). Mycorrhizae may play a role in seed germination (Quintana 2020, in litt.). At least one species of *Ochrosia* (*O. elliptica*) has been propagated by both seed and ripe wood cuttings (Plant Resources of South East Asia 2020 cited in Useful Tropical Plants 2014b), and it is recommended that seeds of *O. moorei* (an Australian endemic) be excised from the fruits and sown immediately to preserve viability.

Propagation experts report that individuals of *Ochrosia haleakalae* under propagation have low to medium water requirements and can become drought tolerant once established, low fertilizer on occasion is good, and requires well-drained cinder soil and full sun (i.e., at least 8 hours of direct sunlight per day) (Romanchak 2020 in Native Plants 2020; Native Plants Hawaiʻi 2020). Habitats in which wild *O. haleakalae* is known to occur include dry grasslands and shrublands (Peʻa et al. 2020, entire), mesic grasslands and shrublands (Ball et al. 2020, entire), mesic forest (Lowe et al. 2020, entire), wet grasslands and shrublands (Nelson et al. 2020, entire), and wet forest (Clark et al. 2020, entire). Abiotic features of these habitats, in areas that are known to support *O. haleakalae*, are summarized below in Table 1. For further information regarding these habitat types, including associated species and factors influencing habitat quality, please refer to the detailed habitat assessments for each respective habitat type cited above. It is reasonable to deduce that *O. haleakalae* trees, at minimum, require sufficient space to grow, an annual precipitation ranging from 25 to 170 in (637 to 3,409 mm), elevation from 1,316 to 4,006 ft (401 to 1220 m), flat to over 45 degree slope topography, and a temperature range of 61 to 69 °F (16 to 20.5 °C), in the respective habitat types (see Table 1). However, it is probably not this simple. Myriad factors act synergistically to create the right environment that support *O. haleakalae* trees. For example, higher rainfall may be tolerable if the drainage is good, or low amount of rainfall may be equally tolerable if the soil has moisture retention properties. Because the species occurs in multiple habitat types, the populations in each respective habitat type may be adapted to specific habitat conditions therein and possess unique traits to that population site. However, *O. haleakalae* does exhibit adaptability. Seeds collected in dry grassland and shrubland habitat on Maui were used to successfully introduce the species into wet forest habitat within Hawaiʻi Volcano NP on the island of Hawaiʻi (see **Current Condition**). Despite *O. haleakalae* individuals in propagation exhibiting some drought tolerance once established (Native Plants Hawaiʻi 2020), and wild populations occupying dry grassland and shrubland habitat, more of the current extant populations are found in mesic habitat than in dry habitat, which indicates having at least moderate precipitation is important for individuals to survive. A decline in individuals in dry habitat may also be the result of increase in incidence and duration of drought in Hawaiʻi over the past 50 or more years (NOAA 2021, p. 1).

Table 1. Abiotic features of habitat types at recorded locations[1] of *Ochrosia haleakalae*.

| **Habitat Type[1]** | **Average annual precipitation: in (mm)** | **Soil type(s)** | **Topography: percent slope[2]** | **Approximate Elevation: ft (m)** | **Approximate Average annual temperature: Fahrenheit (°F) (Celsius (°C))** |
|---|---|---|---|---|---|
| **Dry grasslands and shrublands** | 25 in (637 mm) | Lava flow (ʻaʻā, rough[3]) | 23 percent | 2,087 ft (636 m) | 68 °F (20 °C) |
| **Mesic forest** | 73 in (1,861 mm) | Highly erodible land, Hanipoe silt loam | 2–40 percent | 3,937 ft (1,200 m) | 61 °F (16°C) |
| **Mesic grasslands and shrublands** | 28–74 in (717–1,870 mm) | Potentially (Hanipoe silt loam) or highly (Kekake extremely rocky muck) erodible land | 9–60 percent | 4,006 ft (1,221 m) | 61–63 °F (16–17 °C) |
| **Wet grasslands and shrublands** | 129 in (3,276 mm) | Highly erodible land, rough broken land | 98 percent | 1,316 ft (401 m) | 69 °F (20.5°C) |
| **Wet forest** | 170 in (3,409 mm) | Potentially highly erodible (Honokaa silty clay loam and Honomanu-Amalu association) | 21–29 percent | 3,268 ft (996 m) | 61–64 °F (16–18 °C) |

1. For the full range of precipitation, elevation, and temperature for each habitat type, please see their respective habitat assessments cited in the text. Note: some of the grassland and shrubland habitats were previously their respective forest habitat type (see Figure 4a through 4e).
2. One-hundred percent slope = 45 degree slope; a slope above 45 degrees equates with an increase in slope percent above 100 percent (a more steep slope), a slope lower than 45 degrees equates with a percent slope lower than 100 degrees (a less steep slope).
3. Lava with a rough, rubbly surface, not highly erodible.

The pollination and seed dispersal mechanisms of *Ochrosia haleakalae* are unknown; however, there are a few reports for congeneric (other species within the genus) species. Some *Ochrosia* species reportedly have floral nectaries, which is indicative of biotic pollination (Lorence and Butaud 2011, pp. 96, 99). In addition, several *Ochrosia* species are reportedly pollinated by insects (Barry and Thomas 1994, in litt.; Useful Tropical Plants Database 2014a; Useful Tropical Plants Database 2014b; Useful Tropical Plants Database 2014c). A study in the Bonin Islands found that flowers of *O. nakaiana* were visited by honey bees, "other bees", moths, beetles, flies, and ants (Abe 2006, p. 327 and Appendix Table A1); however, only honey bees and ants were observed visiting the extrafloral nectaries (Abe 2006, p. 327). Seeds of congeneric species are reportedly dispersed by water (Fall et al. 2007, Appendix 1; Simões et al. 2016, p. 99), various frugivorous birds and/or ground dwelling mammals (Barry and Thomas 1994, in litt.; Fall et al. 2007, Appendix 1), and bats and crabs (Fall et al. 2007, Appendix 1).

As the breeding system of *Ochrosia haleakalae* is unknown, we look to the general study conducted by Sakai et al. (1995, p. 2,524) to make inferences for this species. Sakai et al. (1995, p. 2,524) studied the colonists of the flora of the Hawaiian islands to determine the breeding system of the colonist's lineage, the assumed breeding system of the colonist, the breeding system of the current species, the assumed pollinator of the colonists, and the assumed dispersal method. According to Sakai et al. (1995, p. 2,524) the presumed breeding system of both the colonist and current species are monomorphic, the assumed breeding system of the colonist was hermaphroditic. The assumed pollinator of the colonist was insect and the assumed original long distance dispersal method was oceanic drift. Based on the results of this study, we hypothesize that the breeding system for *O. haleakalae* is hermaphroditic, and flowers are perfect with both male and female function. Additionally, we assume that the fleshy fruits of this species may be dispersed oceanic drift (Sakai et al. 1995, p. 2,524)).

*Ochrosia haleakalae* is the first species within the Hawaiian *Ochrosia* to have a chromosome count analysis. Recent chromosome analyses carried out by Kiehn and Lorence (2019, pp. 412, 415) found that *O. haleakalae* is a tetraploid species, with a somatic chromosome number of 2n=44 to 48 (and a base number of x=11 or 12). As earlier studies of a few congeneric species outside of the Hawaiian archipelago reported diploid *Ochrosia* species with 2n=20 or 2n=22 chromosomes (x = 10 or 11 chromosomes) (Kiehn and Lorence 2019, pp. 412, 415, Kiehn 2020, pers. comm.), the polyploidy situation of *O. haleakalae* might have developed in the Hawaiian archipelago (Kiehn and Lorence 2019, pp. 412, 415). Polyploidy is common in flowering plants, primarily in chromosome-pair multiples, and can often lead to increased vigor (e.g., gene redundancy and loss of self-incompatibility) (Comai 2005, pp. 836–839; Woodhouse et al. 2009, pp. 1–4). Benefits of being polyploidy can play an important role when small isolated populations are forced to inbreed (Woodhouse et al. 2009, p. 1), which is unfortunately relatively common in extant endangered Hawaiian plant species. However, there can be disadvantages of polyploidy in plants. Plants with an odd number of chromosome sets (e.g., triploid and pentaploid) appear morphologically normal, but are often, but not always, infertile and limited to vegetative reproduction (Pearson 2001, in litt.; Woodhouse et al.2009, in litt.; Taylale and Parisod 2013, p. 82). Additionally, the increase in genomic material results in enlarged cells, which may disrupt normal cell processes (Comai 2005, pp. 836–839; Woodhouse et al. 2009, pp. 1–4).

In summary, we know that *O. haleakalae* grows primarily in the dry, mesic and wet forest, as well as grassland and shrubland habitat; with soil ranging from lava to wet Honokaa silty clay loam; a rather wide range of annual precipitation; full sun to partial canopy and may require insect pollinators. Additionally, seeds are probably dispersed by water and/or animals. No detailed reproductive studies have been conducted on *O. haleakalae*, or any of the other 39 or so species within the genus *Ochrosia*. Therefore, it is unknown if *O. haleakalae* relies solely on outcrossing or if it is capable of auto- or self-pollination.

**Population Needs**
In this Species Report, the working definition of a population for plants is: "a group of conspecific individuals that are in close proximity to each other (i.e., less than 1,000 m apart), and are presumed to be genetically similar and capable of sexual (recombinant) reproduction" (HPPRCC 2011, p. 1). A healthy population consists of abundant individuals with a sufficient quantity of quality (i.e., meets all the biotic and abiotic needs of the species and has minimal threats) habitat to maintain survival, reproduction, and recruitment in spite of disturbance.

Suitable habitat for *Ochrosia haleakalae* occurs primarily in forests, as well as grasslands and shrublands, between approximately 1,316 to 4,006 ft (401 to 1,220 m) elevation (Wagner et al. 1999, p. 218; Service 2016a, p. 67,801; Service 2020, unpublished data), as described under Individual needs. Although pollination and seed dispersal mechanisms are not known for *O. haleakalae*, research on congeneric species indicates *O. haleakalae* flowers may be pollinated by insects, and seeds are probably dispersed by water and/or animals (see Individual Needs). Therefore, populations of *O. haleakalae* probably require sufficient healthy populations of unknown insect pollinators as well as water (e.g., precipitation, streams, and ocean currents) and/or animals for seed dispersal. Typically, it is coastal species of *Ochrosia* for which water is suggested as a mechanism of seed dispersal; however, it has also been suggested as the mechanism for how *Ochrosia* made its way to the Hawaiian Archipelago. It may also be how *Ochrosia* dispersed across the main Hawaiian islands. Additionally, because *O. haleakalae* can grow on a variety of slopes, it is possible to suggest trees growing on a steep slope will naturally have seeds dispersed by gravity and precipitation, as well as by frugivorous and/or omnivorous animals. Although we know little about the reproductive needs of *O. haleakalae*, cross-pollination within and among populations contributes to resilient populations for many flowering plants. If *O. haleakalae* is capable of or relies upon outcrossing, then this would be maintained in a resilient population.

In order to be resilient, populations of *Ochrosia haleakalae* also need to have a healthy and either stable or increasing population growth, with at least some connectivity to other *O. haleakalae* populations. Natural regeneration is an important factor in population resiliency, as well as population size, structure (various stages of growth), and again, sufficient quantity of quality habitat. Herein, population resiliency is measured by population size, recruitment and regeneration (if known), and habitat quality.

**Species Needs**
The species needs for *Ochrosia haleakalae* are very similar to those of the individual and population needs, just on a larger scale. The species needs to have multiple resilient populations (stable or increasing population growth with all life stages well represented, and sufficient

quantity of quality habitat) that are redundant (spread out across the geographic range of the species) and well represented (maintains genetic and environmental diversity). Therefore, *O. haleakalae* needs multiple resilient populations to occur within each of the unique habitat types it is known to occur (see Table 1), across the entire geographic range of the species (on both Maui and Hawaiʻi), including the full spectrum of elevation (1,316 to 4,006 ft (401 to 1,220 m)), precipitation (25–98 in (637 and 3,409 mm)), and temperature ( 61–69 °F (167 and 20.5 °C)) ranges (USFWS 2020, unpublished data). These resilient populations also require a distribution that allows for connectivity among populations, while maintaining multiple populations to prevent catastophic events from negatively affecting the majority of individuals at the same time. There are no known distinct morphological variations observed among the populations of the species.

## FACTORS INFLUENCING VIABILITY

**Threats and Conservation Actions**
Since the arrival of humans, habitats in the Hawaiian Archipelago have undergone myriad changes. This is particularly true for habitats within lower elevation areas. However, over time, impacts from human-associated activities have reached further into nearly all habitats at all elevations across the main Hawaiian islands. Primarily, it is nonnative animals and plants that have, and continue to, modify or destroy native habitats that support *Ochrosia haleakalae* (USFWS 2016a, entire). Additionally, some of these nonnative animals also eat and/or trample individuals of *O. haleakalae*. Stochastic events such as wildfire, and hurricanes also negatively affect the habitats that support *O. haleakalae*, and can directly injure or kill individuals or entire populations under catastrophic conditions. Because current extant populations of *O. haleakalae* are small, they are at greater risk from catastrophic events compared to the species' pre-human populations. Due to the persistence of human-associated factors that influence the viability of *O. haleakalae* overtime, the species' range has retracted, its number of populations decreased, and its number of wild individuals has decreased. Climate change will exacerbate many, if not all, of these factors. Despite the attempts (i.e., promulgation of laws and policies) by State and Federal regulatory agencies, there are insufficient regulatory mechanisms in place to address all of the above human-associated factors, particularly factors involving biosecurity. Individually, and even more so cumulatively, the above listed human-associated factors influence viability of the *O. haleakalae* by reducing the resiliency of its extant populations, and reducing the redundancy and representation of the species. Below we provide examples of how each of the human-associated factors influence the viability of *O. haleakalae.* Conservation efforts that are being implemented to reduce or eliminate the impacts on the species are discussed under **Conservation Actions** in the following section.

<u>Nonnative animals and plants</u>
Feral pigs and goats modify and destroy the habitats of *Ochrosia haleakalae* on both Maui and the island of Hawaiʻi, and cattle and deer modify and destroy the habitat of this species on Maui (Medeiros et al. 1986, p. 51; Oppenheimer 2015, pers. comm.; Oppenheimer 2020, pers. comm.). Habitat destruction decreases the available habitat for *O. haleakalae,* which limits the number and size of possible *O. haleakalae* populations resulting in reduced resiliency, redundancy, and representation. Herbivory by these animals, as well as slugs and rats, occurs throughout the range of this species, sometimes only in specific habitat types throughout its range (e.g., slugs in mesic

to wet habitats), further lowering resiliency of populations by limiting their ability to reproduce and regenerate, and possibly increasing their susceptibility to disease. Seed predation by slugs and rats (Oppenheimer 2015, pers. comm.) further lower regeneration throughout much of the species' range. Ants farming soft scale sap-sucking insects are also reportedly a threat to *O. haleakalae* (HBMP 2010). For further information on how these nonnative animals impact *O. haleakalae* and its habitats, please refer to the proposed and final listing rules (USFWS 2015, entire, 2016a, pp. 67,824–67,851) and the detailed habitat assessments for each habitat type (see Table 1).

Nonnative plant species such as *Cestrum diurnum* (day cestrum), *Fraxinus uhdei* (tropical ash), *Psidium cattleianum* (strawberry guava), *P. guajava* (guava), *Rubus* argutus (sawtooth blackberry or highbush blackberry), *Setaria palmifolia* (palmgrass), and *Toona ciliata* (red cedar or toon tree), modify and destroy habitat and outcompete native plants for essential nutrients, including *O. haleakalae* (HBMP 2010). In dry areas, the possibility of wildfires affecting the habitat of this species is exacerbated by the presence of introduced grass species such as *Cenchrus clandestinus* (kikuyu grass) (HBMP 2010; Oppenheimer 2015, pers. comm.). In dryer habitat on Maui, nonnative invasive plants reportedly influencing the viability of *O. haleakalae* include *Bocconia frutescens* (tree poppy or plum poppy), *Neonotonia wightii* (perennial soybean), *Lantana camara* (lantana), *Schinus terebinthifolius* (Christmas berry, Brazilian peppertree). Such species influencing viability in mesic habitats on Maui include *Psidium cattleyanum*, *Fraxinus uhdei* (tropical ash), *Cinchona pubescens* (cinchona, quina), *Spaeropteris cooperi* (Australian tree fern), *Rubus argutus* (sawtooth blackberry), *Setaria palmifolia*, and *Clidemia hirta* (soapbush); and wet habitats on Hawaiʻi include *Tibouchina herbacea* (cane tibochina, glorytree), *Setaria palmifolia* (palmgrass), *Hedychium coronarium* (Hawaiian white ginger, white butterfly ginger, butterfly lily), *H. gardnerianum* (kahili ginger), *H. flavescens* (yellow ginger), *Psidium cattleianum* (strawberry guava), and *Passiflora mollissima* (banana passion fruit); and grasses such as *Paspalum conjugatum* (Hilo grass, buffalo grass), *P. urvillei* (Vasey's grass), and *Axonopus fissifolius* (carpetgrass).

<u>Stochastic events</u>
Wildfires and hurricanes directly and indirectly influence the viability of *Ochrosia haleakalae*. As populations decrease number and size, they become less likely to withstand such stochastic events.

Incidence of wildfires has increased with the presence of humans, and is exacerbated during times of drought-which is anticipated to increase in frequency and duration due to climate change (Trauernicht 2014, in litt.; Gregg 2018, p. 21). The spread of fire tolerant nonnative plants (e.g., kikuyu grass) within the dry forest and dry grasslands and shrublands habitats further exacerbates the risk of wildfire to populations of *Ochrosia haleakalae* and its habitat. (HBMP 2010; Oppenheimer 2015, pers. comm.). For further information on how fire impacts habitats in the Hawaiian Archipelago, please refer to the proposed and final listing rules (USFWS 2015, p. 58,869, 2016a, p. 136), the detailed habitat assessments for the relevant habitat type(s) (see Table 1), and the Pacific Fire Exchange (2020).

In recent years, the Hawaiian archipelago has experienced several hurricanes. Due to warming sea temperatures associate with climate change, the Hawaiian archipelago is anticipated to experience an increase in hurricane frequency and intensity. For details regarding the history of hurricanes in the Hawaiian archipelago and how hurricanes may affect *Ochrosia haleakalae* and its habitats, see the final listing rule (USFWS 2016a, entire).

<u>Climate Change</u>
Climate change may result in alteration of the environmental conditions and ecosystems that support *Ochrosia haleakalae*. *Ochrosia haleakalae* may be unable to tolerate or respond to changes in temperature or moisture, or may be unable to move to areas with more suitable climatic regimes (Fortini et al. 2013, p. 83). For more information on how climate change may impact *O. haleakalae* and its habitat, see the final listing rule (USFWS 2016a, entire) as well as the habitat assessments for each habitat type that supports *O. haleakalae* (see Table 1).

<u>Low regeneration</u>
The listing rule (USFWS 2016a, pp. 67,801, 67,849) cites low reproduction in the wild as a threat to *Ochrosia haleakalae*. New data show that the largest population of approximately 250 to 350 individuals, located in the Auwahi ahupuaʻa, has at least some natural regeneration within three fenced exclosures (not all individuals in this population are within the exclosures). In addition, outplanted individuals in this area are also regenerating. There is also regeneration in the population within the Makawao population. Two introduced populations in Hawaiʻi Volcano National Park are also naturally regenerating. It is unknown if natural regeneration occurs at any of the other population sites, or whether any of the observed regeneration is sustantial enough to support stable population structure. Because many of the populations are small, not within fenced exclosures, and/or do not receive regular conservation action, limited regeneration likely influences some of the populations. Conservation and restoration actions at Auwahi and Hawaiʻi Volcano National Park show that if populations are large, protected from nonnative ungulates, and received regular conservation actions (e.g., nonnative species control), natural regeneration may occur. Loss of natural regeneration at some populations could lead to reduced vigor and diminished capacity to adapt to environmental changes, subsequently influencing this species' long-term persistence (USFWS 2016a, p. 67,849).

<u>Inadequate Regulatory Mechanisms</u>
Inadequate Habitat Protection: Nonnative feral ungulates pose threat to *Ochrosia haleakalae* through destruction and degradation of the species' habitat and herbivory but regulatory mechanisms are inadequate to address this threat (USFWS 2016, entire). The State of Hawaiʻi provides game mammal (feral pigs and goats, axis deer, and mouflon sheep) hunting opportunities on State-designated public hunting areas on the islands of Maui and Hawaiʻi (HDLNR 2003, pp. 10–11 and 44). However, the State's management objectives for game animals range from maximizing public hunting opportunities (e.g., "sustained yield") in some areas to removal by State staff, or their designees, in other areas (State of Hawaiʻi, H.A.R. 13-123).

Introduction of Nonnative Plants and Insects: Currently, four agencies are responsible for inspection of goods arriving in Hawaiʻi (USFWS 2016a, pp. 67,843–67,847). The Hawaiʻi Department of Agriculture (HDOA) inspects domestic cargo and vessels and focuses on pests of concern to Hawaiʻi, especially insects or plant diseases. The U.S. Department of Homeland Security-Customs and Border Protection (CBP) is responsible for inspecting commercial, private, and military vessels and aircraft and related cargo and passengers arriving from foreign locations (USFWS 2016a, pp. 67,843–67,847). The U.S. Department of Agriculture-Animal and Plant Health Inspection Service-Plant Protection and Quarantine (USDA-APHIS-PPQ) inspects propagative plant material, provides identification services for arriving plants and pests, and conducts pest risk assessments among other activities (HDOA 2009, p. 1). The Service inspects arriving wildlife products, enforces the injurious wildlife provisions of the Lacey Act (18 U.S.C. 42; 16 U.S.C. 3371 *et seq*.), and prosecutes CITES (Convention on International Trade in Wild Fauna and Flora) violations. The State of Hawaiʻi allows the importation of most plant taxa, with limited exceptions (USFWS 2016a, pp. 67,843–67,847). It is likely that the introduction of most nonnative invertebrate pests to the State has been and continues to be accidental and incidental to other intentional and permitted activities. Many invasive weeds established on Hawaiʻi have currently limited but expanding ranges. Resources available to reduce the spread of these species and counter their negative ecological effects are limited. Control of established pests is largely focused on a few invasive species that cause significant economic or environmental damage to public and private lands, and comprehensive control of an array of invasive pests remains limited in scope (USFWS 2016a, pp. 67,843–67,847).

<u>Conservation Actions</u>

The conservation actions that either directly or indirectly benefit *Ochrosia haleakalae* vary from site to site across its range. The existing populations, whether wild, augmented, or introduced, are largely due to conservation actions implemented by private landowners, such as the Auwahi Forest Restoration Prject at ʻUlupalakua Ranch, Hawaiʻi Department of Land and Natural Resources Division of Forestry and Wildlife (HDOFAW), University of Hawaiʻi Plant Extinction Prevention Program (PEPP), and Hawaiʻi Volcano National Park (NP). Monitoring, threat control, seed collection, propagation, and outplanting takes place by partners on both Maui and Hawaiʻi. Several ungulate-exclusion fences have also been installed which protect a substantial portion of the largest population on Maui and two healthy introduced populations on Hawaiʻi (see Table 2 and Table 3). Fencing to exclude nonnative ungulates is one of the most beneficial conservation actions, as long as the ungulates are removed from within the exclosure once completed. Fence maintenance is also important to avoid openings that let the respective ungulates inside. Ungulates are managed in Hawaiʻi as game animals, but public hunting does not adequately control the numbers of ungulates to eliminate habitat modification and destruction, and herbivory by these animals (Anderson et al. 2007, in litt.; HAR-DLNR 2010, in litt.). Rat and slug control takes place within some of the fenced exclosures, some of the time. Some amount of nonnative plant control is also implemented within these exclosures. In ungulate-free exclosures, such as in the Hawaiʻi Volcano NP introduced sites, Auwahi, and some watershed partnership exclosures, focus is primarily on actions such as nonnative plant, rat, slug, and ant control.

Most of the sites that support current or historic populations of *O. haleakalae* are within the boundaries of one of Hawaiʻi's watershed partnerships (WP) (see Table 2 and Table 3). These watershed partnerships, which are comprised of private and public partners, implement a variety of conservation actions (fencing, ungulate and other nonnative animal removal and control, and nonnative plant control). Fencing, nonnative species control, and plant propagation and outplanting the primary actions implemented by our private, Federal, and State partners. However, because these actions are costly and labor intensive, reources limit the ability for partners and landowners to conduct and maintain all threat control. Habitat restoration actions implemented outside of known population sites, but within the range of *O. haleakalae* habitat, also benefit *O. haleakalae* as these areas are potential habitat for the species, or may even support yet to be identified individuals or populations.

Three rare plant nurseries, Volcano Rare Plant Facility (VRPF), Olinda Rare Plant Nursery, and Hawaiʻi Volcanoes NP nursery, propagate *O. haleakalae* seeds for outplanting purposes (Hawaiʻi Volcano NP 2019, p. 21; Olinda 2019; VRPF 2019; Oppenheimer 2020, in litt.). Individuals are outplanted within Laupāhoehoe Natural Area Reserve (NAR), Hawaiʻi Volcano NP, and within the Kanaio ahupuaʻa (Maui). The three outplanting sites within Hawaiʻi Volcano NP are outside of the species historic range and therefore expand the range for the species as two of these three sites have observed natural regeneration. Seeds from the Kanaio population were used for the early phases of outplanting efforts within Hawaiʻi Volcano NP. Over time, as the introduced individuals naturally regenerated, seeds were collected from the recruited individuals. The VRPF has collected and propagated seeds from individuals scattered around the slopes of Kohala Mountain and outplanted them within Laupāhoehoe NAR and other sites around Kohala Mountain; however, the survival rate of the outplanted individuals has remained extremely low. Currently, only two outplanted individuals have survived to date. For a summary of which conservation actions occur at each of the known populations of *O. haleakalae* across its range, please see Table 3 and Table 4 under **Current Condition**.

Regulatory Actions

The Endangered Species Act is a regulatory action that can benefit speices. The Service in 2016 determined endangered status under the Endangered Species Act of 1973 (Act), as amended, for 49 plants and animals on September 30, 2016 including *Ochrosia haleakalae* (USFWS 2016, entire). The primary purpose of the Act is the conservation of endangered and threatened species and the ecosystems upon which they depend. The ultimate goal of such conservation efforts is the recovery of these listed species, so that they no longer need the protective measures of the Act. Conservation measures provided to species listed as endangered or threatened under the Act include recognition of threatened or endangered status, recovery planning, requirements for Federal protection, and prohibitions against certain activities. The Act encourages cooperation with the States and requires that recovery actions be carried out for all listed species. The Act and its implementing regulations in addition set forth a series of general prohibitions and exceptions that apply to all endangered wildlife and plants. For plants listed as endangered, the Act prohibits the malicious damage or destruction on areas under Federal jurisdiction and the removal, cutting, digging up, or damaging or destroying of such plants in knowing violation of any State law or regulation, including State criminal trespass law. Certain exceptions to the prohibitions apply to agents of the Service and State conservation agencies. The Service may issue permits to carry out otherwise prohibited activities involving endangered or threatened wildlife and plant species under certain circumstances. With regard to endangered plants, a permit must be issued for scientific purposes or for the enhancement of propagation or survival. For federally listed species unauthorized collecting, handling, possessing, selling, delivering, carrying, or transporting, including import or export across State lines and international boundaries, except for properly documented antique specimens of these taxa at least 100 years old, as defined by section 10(h)(1) of the Act, is prohibited. Damaging or destroying any of the listed plants in addition is violation of the Hawaiʻi State law prohibiting the take of listed species. The State of Hawai‘i’s endangered species law (HRS, Section 195-D) is automatically invoked when a species is federally listed, and provides supplemental protection, including prohibiting take of listed species and encouraging conservation by State government agencies. *Ochrosia haleakalae* occurs on both Federal and non-Federal lands.

## CURRENT CONDITION

Below we consider the Historical Condition, which we use as a baseline to help depict the changes that have taken place over time resulting in the Current Condition.

**Historical Condition**

Pre-human Habitat Distribution and Description

In the absence of humans, and therefore the absence of human-associated threats, the dry, mesic and wet grassland and shrubland, and dry, mesic, and wet forest habitat types were robust and expansive across the main Hawaiian islands (Figure 4a through 4e). Data suggest that some of the grassland and shrubland habitats were formerly their forest counterparts (see Figure 4a through 4e). Some of the historical records of *Ochrosia haleakalae* were reportedly in the dry to mesic forest habitat (Wagner et al. 1999, p. 218), in areas which are now considered grassland and shrubland habitat, indicating that these areas may not currently be suitable for this species. The quantity and quality of the pre-human habitats made them resilient to stochastic events, and due to their distribution at multiple elevations, on two separate islands, these habitats also had enough redundancy (the number, distribution, and connectivity of habitat units) to withstand catastrophic events while also providing for higher representation (species diversity; and geographic, climatic, and ecological diversity). Additionally, the absence of human-associated threats provided for the presence of abundant and diverse native pollinators (e.g., insects, birds, bat), and frugivorous animals to aid in seed dispersal, which together contributed toward the robustness of the habitats. For further information on each of the habitat types and how the Service applies the 3Rs to habitat types, please see the respective habitat conducted by Ball et al. (2020, entire); Clark et al. (2020, entire); Lowe et al. (2020, entire); Nelson et al. (2020, entire); and Pe‘a et al. (2020, entire).

Since the arrival of humans in the islands (approximately 2,000 years ago (Kirch 2011, p. 11)), a gradual but steady modification of the landscape has occurred. Over time, as the human population increased, so did the human-associated impacts on native habitats (see **FACTORS INFLUENCING VIABILITY**). Human-associated habitat modification and destruction started in lower elevation areas and has been spreading further into higher elevations and habitat types, including habitats that support *O. haleakalae* (Figure 4a through 4e). Due to the ongoing human-associated activities described under **FACTORS INFLUENCING VIABILITY**, the habitat that support *Ochrosia haleakalae* have declined in resiliency, redundancy, and representation (see **Current Condition**, below).

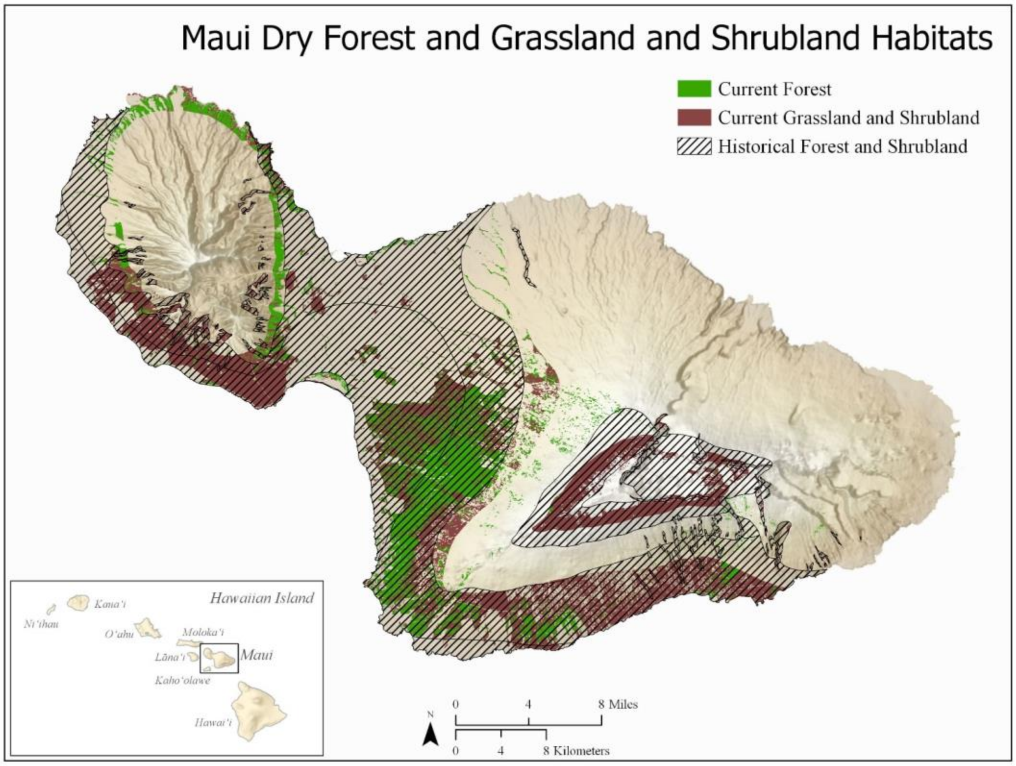


Figure 4. Pre-human and current distribution of dry forest and dry grasslands and shrublands habitat on Maui.

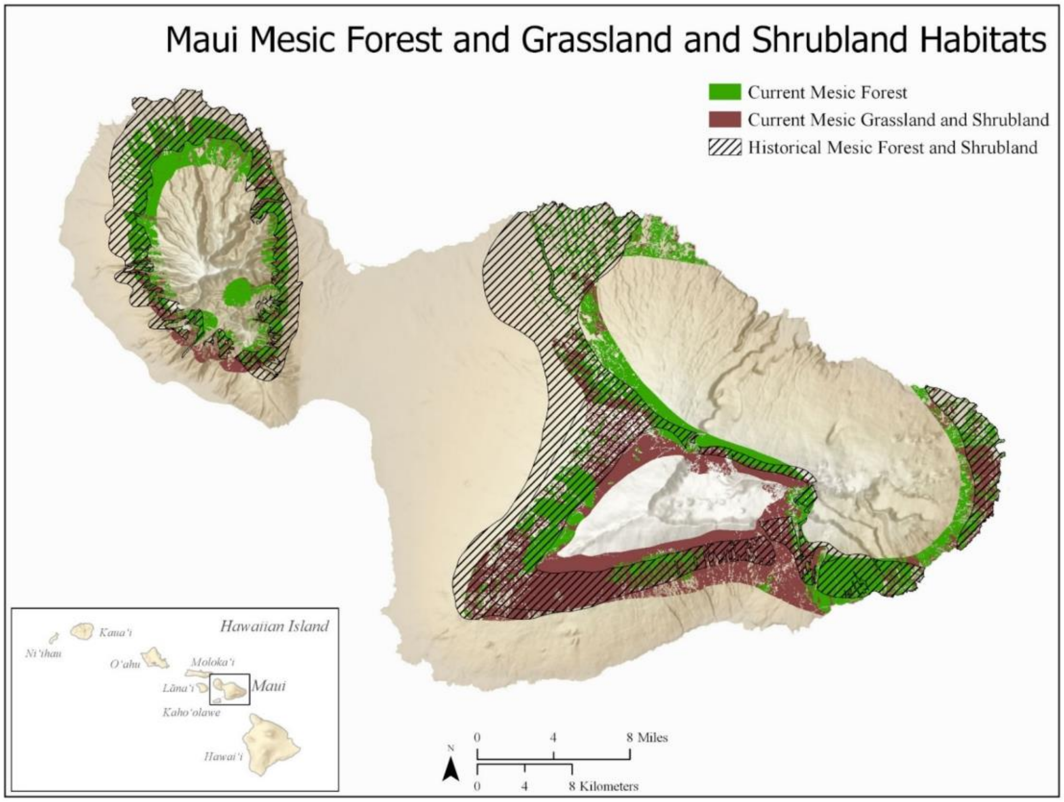


Figure 4b. Pre-human and current distribution of mesic forest and mesic grasslands and shrublands habitats on Maui.

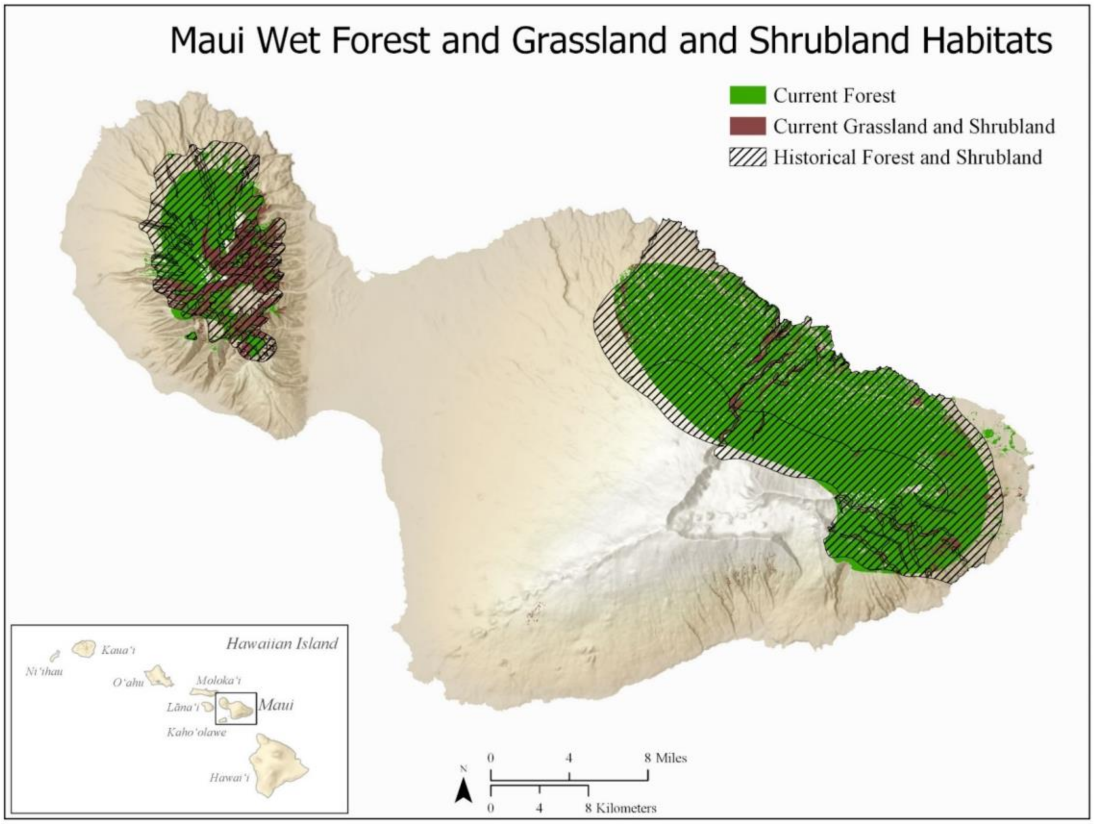


Figure 4c. Pre-human and current distribution of wet forest and wet grasslands and shrublands habitats on Maui.

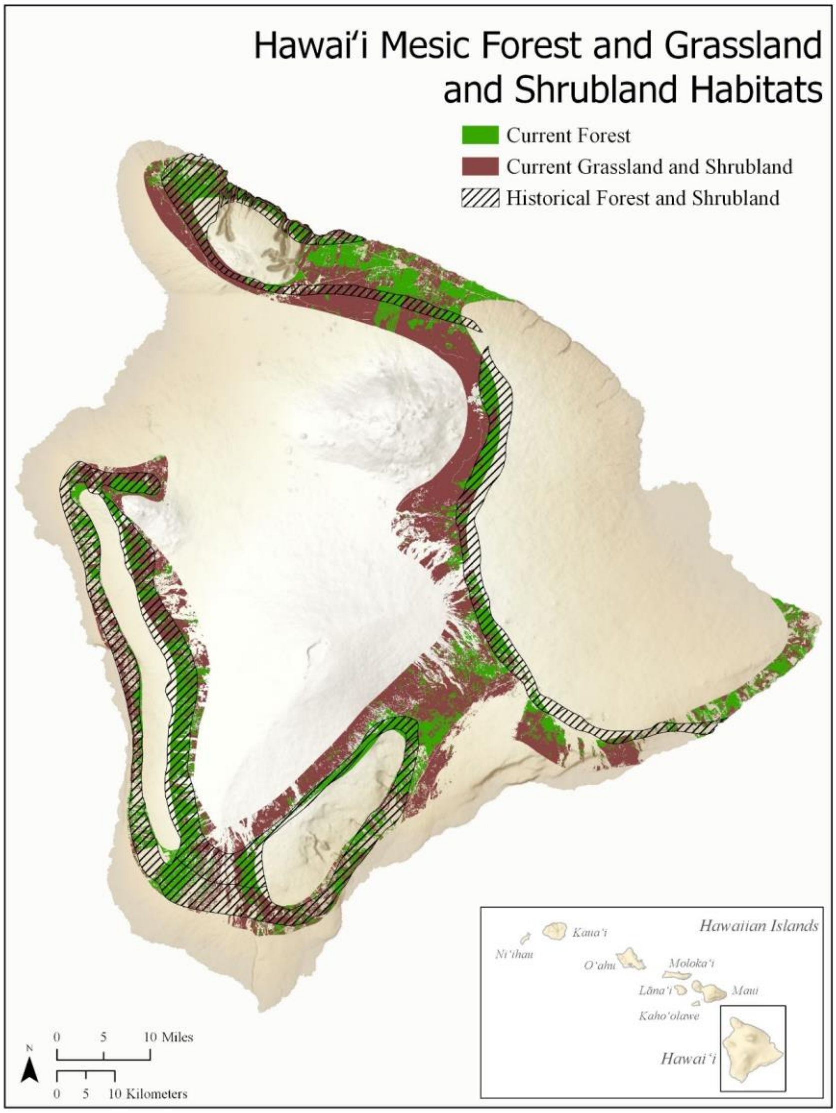


Figure 4d. Pre-human and current distribution of mesic forest and mesic grasslands and shrublands habitats on Hawai‘i.

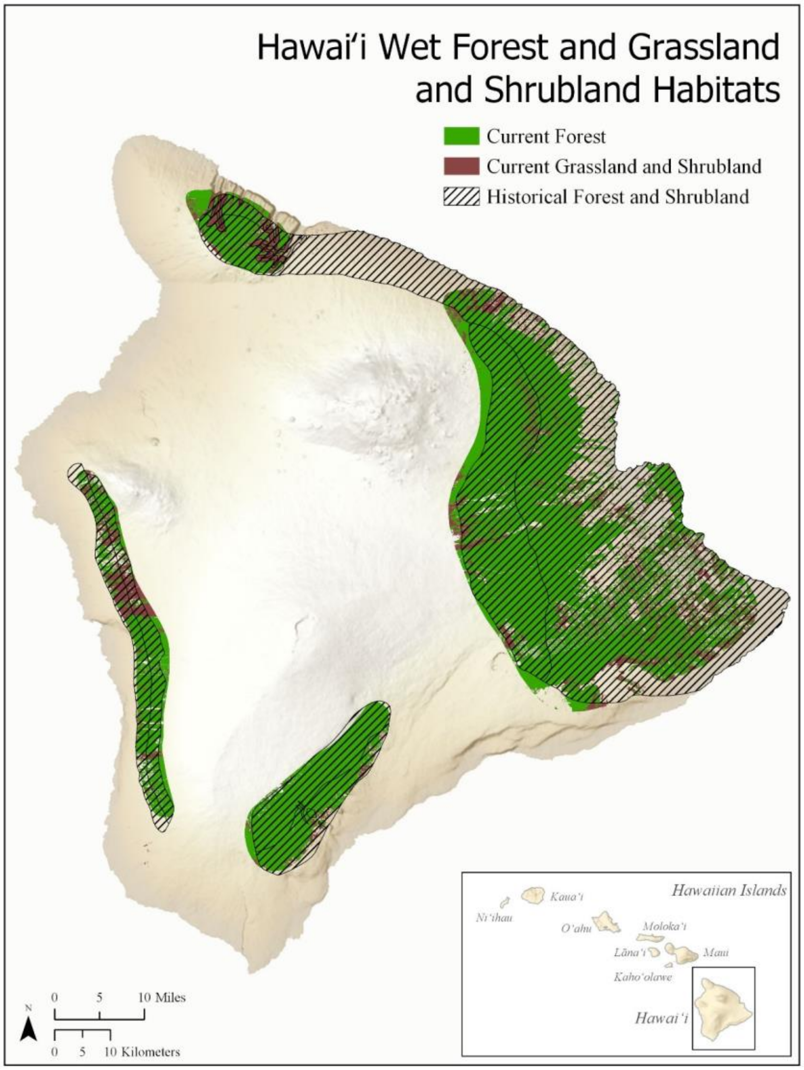


Figure 4e. Pre-human and current distribution of wet forest and wet grasslands and shrublands habitats on Hawaiʻi.

Figure 4 (4a–4e). Pre-human and current distribution of habitats known to support *Ochrosia haleakalae* (dry grasslands and shrublands, mesic grasslands and shrublands, wet grasslands and shrublands, mesic forest, and wet forest). Due to a gap in the data between pre-human and current distribution, forest and grasslands and shrublands habitats are shown on the same maps.

Historic Trends of Ochrosia haleakalae
As noted under Species Description, traditional Hawaiian ecological knowledge includes multiple uses of *Ochrosia haleakalae* (canoes, medicine, and dye), which may indicate it was rather abundant at one time. *Ochrosia haleakalae* was formally described in 1978 by St. John (pp. 200–205), along with 10 other single island endemic Hawaiian *Ochrosia* species. At that time, *O. haleakalae* was believed to be endemic only to the island of Maui. Then, in 1995, a single 20 ft (6 m) tall tree was discovered in a stream, in degraded mesic forest on Kohala mountain on the island of Hawaiʻi (Perlman and Wood 1996, p. 11). Shortly after, Wagner et al. (1999, pp. 216–218) revised the 11 species described by St. John into four species, and St. John's *O. hamakuensis*, believed to be endemic to the island of Hawaiʻi, became a synonym for *O. haleakalae* resulting in a range expansion for the species.

The largest recorded wild populations of *Ochrosia haleakalae* were on Maui, primarily within the Auwahi ahupuaʻa expanding into the adjacent Kanaio ahupuaʻa, on the southern slopes of Haleakalā, and in the Makawao ahupua'a, on the northern slopes of Haleakalā. In 1913, in reference to what was thought at the time to be possibly the only *Ochrosia* taxon in Hawaiʻi, *O. sandwicensis*, Joseph Rock (1913, p. 413) wrote:

"The Holei, which has become rather scarce, inhabits the dry districts on the leeward side of the islands, and is only abundant on the Island of Maui, at an elevation of 2500 feet, back of Makawao, slopes of Haleakala, and on the lava fields of Auahi."

The population of *Ochrosia haleakalae* within the Auwahi ahupuaʻa, although rather localized, has remained the strong hold for the species (Medeiros et al. 1986, p. 55; Medeiros et al. 1998, p. 51; Auwahi Forest Restoration Project 2020, pers. comm.). This population was documented as quite vigorous, with abundant flowers and fruit, with a few small seedlings present in the 1980s (Medeiros et al. 1986, p. 55), and today has between 250 and 350 wild individuals with approximately 1,468 outplanted individuals since 2000, with survivorship at nearly 90 percent (Auwahi Forest Restoration Project 2020, pers. comm.). Many of these outplanted individuals are flowering, fruiting, and demonstrating natural regeneration resulting in augmentation of the wild population (Auwahi Forest Restoration Project 2020, pers. comm.). There are only a few reports of *O. haleakalae* on the north slopes of Haleakalā (BISH 2020; USFWS 2020, unpublished data), only one of which documented more than 25 individuals. In the Makawao Forest Reserve (FR), within the Makawao ahupuaʻa, the cumulative number of mature *O. haleakalae* trees ever documented is approximately 53 individuals (Oppenheimer 2020, pers. comm.). The current estimate of individuals is between 15 and 32 individuals, and there is natural regeneration in this population (Oppenheimer 2020, pers. comm.). There is also a record of at least one tree in the Waiʻōpai ahupuaʻa on the southeastern side of the island.

Since the discovery of *O. haleakalae* on the slopes of Kohala mountain, there has not been a wild population documented with more than 15 individuals on the island of Hawaiʻi (see Table 2 and Figure 5) (HBMP 2010; USFWS 2020, unpublished data). There are no records of large populations of *Ochrosia haleakalae* on the island of Hawaiʻi, and with no observations prior to 1995, we do not know how resilient these populations were historically. In total, there are 12 recorded wild populations, six on Maui and six on Hawaiʻi (see Table 2 and Table 3).

The historic distribution and range for this species includes dry, mesic, and wet habitat types on east Maui and the northeast forest slopes from the Kohala Mountains to Mauna Kea on the island of Hawaiʻi (Wagner et al. 1999, pp. 216–218). This demonstrates that *Ochrosia haleakalae* is a highly adaptable species.

**Current Condition**

*Ochrosia haleakalae* (hōlei) is a tree in the dogbane family (Apocynaceae) endemic to the islands of Maui and Hawaiʻi (Wagner et al. 1999, p. 218). This species occurs in dry, mesic, and wet grassland/shrubland and forest habitat, between 1,316 to 4,006 ft (401 to 1,220 m) (see Figure 5 and Figure 6) (Medeiros et al. 1986, pp. 27–28; Wagner et al. 1999, p. 218; HBMP 2010; Auwahi Restoration Project 2020, pers. comm.; Oppenheimer 2020, pers. comm.; USFWS 2020, unpublished data). The ranges of these habitats have contracted since their pre-human range (see **FACTORS INFLUENCING VIABILITY** and Figure 4a through 4e). Some of the grassland and shrubland habitats were formerly their forest habitat counterparts (e.g. some of the current dry grassland and shrubland habitat used to be dry forest habitat). Additionally, much of what remains is highly degraded, with the exception of fenced conservation sites with active, ongoing conservation (see **FACTORS INFLUENCING VIABILITY** and Table 2 and Table 3).

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When referring to another section within the same document use the typeset of the section in the reference (USFWS 2019, p. 21).
• If the header you are referring to is **ALL CAPS AND BOLD**, reference it as such.
○ Example: Please see **PERSONNEL AND EXPENSES**, above.

There are 12 recorded wild populations of *Ochrosia haleakalae* (six on Maui and six on Hawaiʻi), and four outplanted populations on Hawaiʻi-three of which are translocated populations with source populations originating from the Kanaio population on Maui, and augmented with planted and naturally-recruited individuals. In total, there are 16 recorded population units of *O. haleakalae*. On Maui, *O. haleakalae* is currently known from at least three populations totaling between approximately 270 and 370 individuals (Auwahi Forest Restoration Project 2020, pers. comm.; Oppenheimer 2020, pers. comm.). There are at least three small populations on Maui for which a status update was not available, in Kanaio Natural Area Reserve, Waiʻōpai, and Naʻiliʻili Haele. There is a fourth record, an old record from 1800 in Makawao, which is likely the same population unit as the extant Makawao-Olinda N population unit, as the location was only described as the "woods above Makawao" (BISH 2021; HBMP 2010). The largest population, Kanaio-Auwahi (population L) with between 250 and 350 individuals, occurs in the Auwahi ahupuaʻa. There are three fenced exclosures in this area totaling approximately 150 ac (60 ha) that protect a large portion of this population, but not all of the individuals. The adjacent Kanaio Natural Area Reserve (NAR) is also fenced and contains some of this population, as well as a few individuals in the southern portion of the NAR. The population within Makawao FR (the second largest wild population (N), yet substantially smaller) is not fenced but is naturally regenerating. Unfenced individuals in Auwahi and Makawao are vulnerable to risks associated with nonnative ungulates. For details regarding each population on Maui, including known factors influencing the viability of each population, please see Table 3.

On Hawaiʻi, there are two remaining wild populations, three introduced populations (only two of which have natural regeneration), one reintroduced site, and one site at which the species was extirpated but has since had outplanted individuals. Regarding the wild populations: there are three individual trees between ʻOʻōkala and Humuʻula, observed in 2019 (population F); one site in Honopūʻe (I), observed in 2015 with one individual; two sites, Paʻauilo (G) and Pololū (J), with only one or two individuals each-neither of which have been observed for some time; and one site in Waipiʻo Valley with approximately 13 individuals, which also has not been observed for some time (see Table 2) (Agorastos 2010, pers. comm. and 2011, pers. comm.; Conry 2012, pers. comm.; Hadway 2013, pers. comm.; Perry 2015, pers. comm.; USFWS 2020, unpublished data). The status of the individuals at the latter three population sites is not known at this time. Population D in Laupāhoehoe was extirpated; however, there have been several individuals outplanted at this historic site-one of which remains. There were also individuals outplanted nearby (population E within Laupāhoehoe), but far enough to define the site as a separate population unit according to the definition herein, but similarly, only one individual remains at this site (see Table 2).

Since the discovery of *O. haleakalae* (including its synonym *O. hamakuaensis* and erroneous *O. sandwicensis*) on the island of Hawaiʻi, there have only been small clusters or individual trees reported in the wild. In the 1950s, the National Park Service (NPS) began collecting wild seeds of *O. haleakalae* from trees in Auwahi on Maui for propagation and outplanting within Hawaiʻi Volcano National Park (NP) on Hawaiʻi as a surrogate for the extinct *O. kilaueaensis* (HAVO 2019, p 21). Over the course of decades, the NPS introduced hundreds of *O. haleakalae* within Hawaiʻi Volcano NP resulting in three new populations just outside of the historic range of the species. This translocation effort has resulted in two well-established introduced sites, Kīpuka Puaulu and Kīpuka Kī (both vegetated areas surrounded by lava flows); with at least 148 and 45 surviving individuals, respectively, and both populations demonstrate consistent natural regeneration (HAVO 2019, pp. 20–21). Seeds are continually collected from both wild and planted founders to continue propagation and introduction efforts (HAVO 2019, p. 21; VRPF 2019). Recently, *O. haleakalae* was outplanted at a third site within the park-Kīpuka Ahi (HAVO 2020); however, it will take time to observe if natural recruitment and regeneration occur at this site.

For over a decade, the Volcano Rare Plant Facility (VRPF) has collected seeds from trees on Kohala Mountain for propagation and outplanting (VRPF 2019). Dozens of individuals have been outplanted, but not many have survived (VRPF 2019). Currently, there are individuals persisting at two outplanted sites (one historic site and one site just adjacent to the historical site) within the Laupāhoehoe Natural Area Reserve (NAR) (VRPF 2019). No recruitment has been observed at either of these sites (VanDeMark pers. comm. 2020). With no natural recruitment and regeneration, population E within Laupāhoehoe NAR was not included in our viablity assessment, but because population D was a wild population, it was included. For details regarding each population on Hawaiʻi, please see Table 2 and Table 5.

Table 2. Current and Historic Populations Units of *Ochrosia haleakalae* on the island of Hawaiʻi.

| **Population Unit Name** | **Kīpuka Puaulu** | **Kīpuka kī** | **Kīpuka Ahi** | **Laupāhoehoe** | **Laupāhoehoe** | **ʻOʻōkala to Humuʻula** | **Paʻauilo** | **Waipiʻo Valley** | **Honopūʻe** | **Pololū** |
|---|---|---|---|---|---|---|---|---|---|---|
| Population Unit Letter | A | B | C | D | E | F | G | H | I | J |
| Last Observation Date | 2019 | 2019 | 2017 | 2020 | 2020 | 2019 | 1994 | 1995 | 2015 | 1973 |
| Extant? [1] | Y | Y | Y | Y | Y | Y | Unk | Unk | Y | Unk |
| Population Type[2] | I | I | I | R | R | Wild | Wild | Wild | Wild | Wild |
| Regeneration? | Y | Y | Unk: recent outplanting | N | N | Unk | Unk | Unk | Unk | Unk |
| Habitat Type[3] | Mesic Forest | | | Wet Forest | Wet Forest | Wet Forest | Mesic Forest | Wet G and S | Mesic G and S | Mesic G and S |
| Conservation Actions[4] | Fenced; regular conservation actions; within Hawaiʻi Volcano NP and TMA boundaries; propagation and outplanting | | | | | Within MKWP boundaries | Within MKWP boundaries | Within Kohala WP | Within Kohala WP; collection | Within Kohala WP |
| Land Ownership[5] | Gov-Fed | | | Gov-State | Gov-State | Gov-State | Gov-State | Private | Gov-State | Gov-State |
| Estimated Number of Individual | 185 | 71 | 24 | 1 | 2 | 3 | 2 | 13 | 1 | ≥1 |

1 Y = yes, N = no, Unk = unknown
2 W = wild; R = reintroduction; I = introduction
3 G and S = grasslands and shrublands
4 Fenced = within ungulate exclusion fence, ungulates excluded vary and most do not exclude deer (see Factors Influencing Viability)
5 Gov = government, Fed = federal

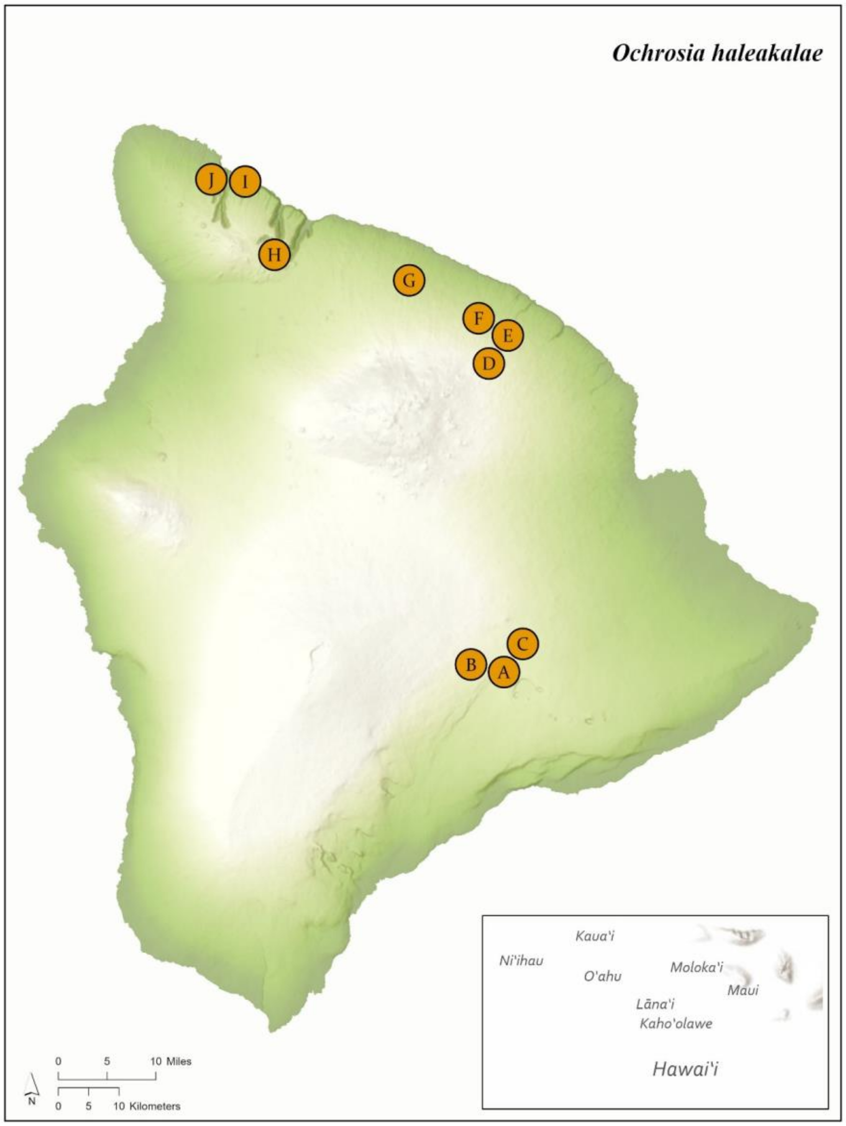


Figure 5. Map of historic and current *Ochrosia haleakalae* populations on Hawai‘i.

Table 3. Current and Historic Populations Units of *Ochrosia haleakalae* on the island of Maui.

| **Population Unit Name** | **Kanaio NAR** | **Kanaio-Auwahi** | **Wai‘ōpai** | **Makawao-Olinda** | **Makawao-Olinda** | **Na‘ili‘ili Haele** |
|---|---|---|---|---|---|---|
| Population Unit Letter | K | L | M | N | O | P |
| Last Observation Date | 2016 | 2020 | 1970 | 2020 | 1800 | 1920 |
| Extant? (Y/N/Unk)[1] | Y | Y | Unk, likely N | Y | Unk, likely unit N[2] | Unk, likely N |
| Population Type[3] | W | W and A | W | W | W | W |
| Regeneration | N | Y | N | Y | See pop unit N | N |
| Habitat Type[4] | Dry G and S | Mesic G and S | Mesic Forest | Mesic Forest | Mesic G and S | Wet Forest |
| Conservation Actions[5] | Ungulate exclusion fence, ungulate free | 3 ungulate exclusion fences, but not all individuals in population are in exclosures; Leeward Haleakala WP | No ungulate exclusion fencing; lies within the lands of Leeward Haleakala WP | No ungulate exclusion fencing; but within the lands of East Maui WP and Makawao FR | | No ungulate exclusion fencing; but lies within the lands of East Maui WP |
| Land Ownership[6] | Gov-State | Private | Gov-State | Gov-State | | Gov-State |
| Estimated Number of Sites | 1 | ≥3 | 1 | ≥1 | 1 | 1 |
| Estimated Number of Individual | ≥4 | 250–350 wild; 1,320 outplanted with natural regeneration | ≥1 | 15–32 | ≥1 | ≥1 |

1 Y = yes, N = no, Unk = unknown
2 Record indicates "woods above Makawao"; assumes refers to population unit N
3 W = wild; R = reintroduction; A = augmented; I = introduction (translocation)
4 G and S = grasslands and shrublands
5 Fenced = within ungulate exclusion fence, ungulates excluded vary and most do not exclude deer (see Factors Influencing Viability)
6 Gov = government, Fed = federal

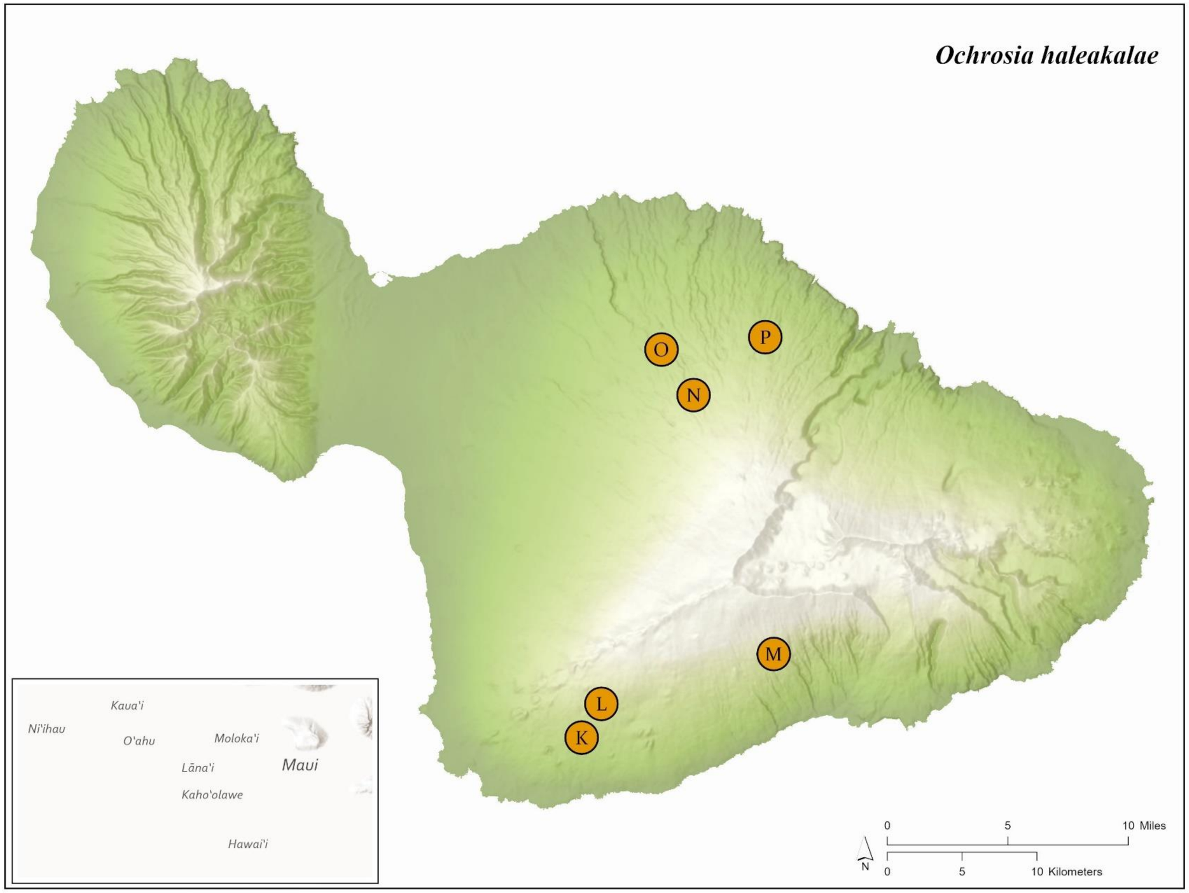


Figure 6. Map of historic and current *Ochrosia haleakalae* populations on Maui.

## SPECIES VIABILITY SUMMARY

As outlined under **INTRODUCTION**, resiliency is the capacity of a population (or a species) to withstand stochastic disturbance events. In this species report, we evaluate the current resiliency for *Ochrosia haleakalae* using the metrics of population size, habitat quantity and quality, observed recruitment (seedlings present) and regeneration (seedlings grow into mature plants), and ongoing conservation actions that benefit the species. Redundancy is defined as the ability of a species to withstand catastrophic events. We evaluate the current redundancy of *O. haleakalae* using the number of populations, the resiliency of each population, and the distribution of the populations throughout the range of the species. Representation is defined as unique traits represented throughout multiple populations across the range of the species. We can measure representation based on the genetic diversity and environmental diversity (i.e., habitat variation) within and among populations.

**Resiliency**
There are approximately 12 recorded wild populations (some consisting of only very small clusters of individuals, or individual trees) of *Ochrosia haleakalae* from the last 100 years, six on Maui and six on Hawaiʻi (see Table 2 and Table 3, and Figure 5 and Figure 6). There is a record of a tree on Maui from the 1800s, in the Makawao ahupua'a, for which little data was recorded and no subsequent data exists, and we assume that this tree was part of the current population of *O. haleakalae* within the Makawao FR (population unit N). Additionally, there are two introduced populations in Hawaiʻi Volcano NP, both of which have natural recruitment and regeneration and were therefore included in our resiliency analysis. In total, there are 14 populations included in our analysis. There are two more outplanted populations (Laupāhoehoe, populations D and E) and one more introduced population (Kīpuka Ahi, population C), all on Hawaiʻi; however, because the outplanted individuals have not naturally regenerated and the newly introduced population was only recently outplanted, these three populations are not included in our analysis.

Of the six wild populations recorded on Maui over the last 100 years, only three are confirmed to still be extant. Of the six wild populations on Hawaiʻi, only two (ʻŌʻōkala to Humuʻula population (population F) and Honopūʻe (population I)) are known to still be extant. In total, under current condition, there are five extant wild populations of *O. haleakalae* across the species range. Of these populations (three on Maui, two on Hawaiʻi), only one (population L, Kanaio–Auwahi) has sufficient individuals with varying life-stages across a large enough area to be considered moderately resilient. This is largely due to ongoing conservation actions implemented for the species and its habitat. The remaining three populations do not have the population size or structure to be considered resilient. Population K (Kanaio) is within a fenced exclosure and has moderate quantity and quality habitat; however, because there are only four individuals, this population is at great risk from any stochastic event. Similarly, the population in Makawao ahupuaʻa (population N, Makawao–Olinda) may have 15–32 individuals with natural regeneration (Oppenheimer 2020, pers. comm.), but this population is not in a fenced exclosure and thus susceptible to ongoing habitat degradation and herbivory by nonnative ungulates. There is likely enough habitat to support a large population, but it would not all be considered suitable due to its poor quality. Additionally, this population is small enough to be at great risk from stochastic events. The ʻŌʻōkala to Humuʻula population (population F) and Honopūʻe (population I) on Hawaiʻi, also have a very low number of individuals (three and one, respectively), and no protections against ungulates, and therefore, both have very low resiliency.

Because the Kīpuka Puaulu (~200 individuals) and Kīpuka Kī (~50 individuals) populations, (populations A and B, respectively) on Hawaiʻi have a relatively high number of individuals per population with active and ongoing natural regeneration, we have included them in our analysis. Although the exact number of recruited individuals that reached maturation (regeneration) resulting from these two introduced populations is not known, it is estimated to be at least 12 (Kīpuka Puaulu) and 18 (Kīpuka Kī) individuals (HAVO 2019, pp. 21–22). Both of these populations are within fenced exclosures on Federal land with ongoing conservation actions. Focusing on the recruited individuals, we evaluate the resiliency of these two populations to be low to moderate. These populations have a low to moderate chance of surviving a stochastic event. As the populations continue to be augmented, the dependence on human intervention by means of conservation actions cannot be overstated.

In summary, including the two introduced populations on Hawaiʻi, there are seven extant populations of *Ochrosia haleakalae* across the range of the species. One of these populations has moderate resiliency (population L (Auwahi, Maui)), but is dependent on ongoing conservation actions. One of these seven populations (population B (Kīpuka Kī, Hawaiʻi)) has low to moderate resiliency, but is also dependent on ongoing conservation actions. The remaining populations have very low resiliency primarily due to their low number of individuals. With only one population assessed as moderate (Kanaio-Auwahi), two assessed as low to moderate (Kīpuka Puaulu and Kīpuka Kī), one assessed as low, and the remaining 10 populations assessed as either very low or extirpated, we assess the overall resiliency for *O. haleakalae* as low. Without the natural recruitment and regeneration within the Hawaiʻi Volcano NP introductions, the overall resiliency would be very low. See Table 4 for a summary of resiliency among these populations.

Table 4. Assessed resiliency of *Ochrosia haleakalae* populations.

| Population | Name | Resiliency |
|---|---|---|
| A | Kīpuka Puaulu | Low to moderate (only naturally recruited and regenerated individuals considered, not introduced individuals), fenced |
| B | Kīpuka Kī | Low to moderate (only naturally recruited and regenerated individuals considered, not introduced individuals), fenced |
| C | Kīpuka Ahi | Not included in analysis because newly introduced site |
| D | Laupāhoehoe | Extirpated, only one individual reintroduced with no regeneration |
| E | Laupāhoehoe | Not included in analysis because reintroduced in site adjacent to extirpated site, only one individual with no regeneration |
| F | ʻOʻōkala to Humuʻula | Very low, only 3 individuals, ungulates present |
| G | Paʻauilo | Likely extirpated |
| H | Waipiʻo | Likely extirpated |

| | | |
|---|---|---|
| I | Honopūʻe | Very low, only1 tree |
| J | Pololū | Likely extirpated |
| K | Kanaio | Very low, only 4 trees |
| L | Kanaio–Auwahi | Moderate, most fenced, augmented, with natural recruitment and regeneration |
| M | Waiʻōpai | Likely extirpated |
| N | Makawao–Olinda | Low, 15 to 32 individuals, some regeneration |
| O | Makawao–Olinda | Likely population unit N, see row above |
| P | Naʻiliʻi Haele | Likely extirpated |

**Redundancy**
We evaluate the current redundancy of *O. haleakalae* using the number of populations, the resiliency of each population, and the distribution of the populations throughout the range of the species. As discussed under **Resiliency**, above, out of the 16 known populations (wild, outplanted, and introduced) within the past 100 or so years, only five wild populations are confirmed to persist plus the two naturally regenerating populations within Hawaiʻi Volcano NP. Of these seven existing populations, three are on Maui and four are on Hawaiʻi. On Maui, two are on the southern slopes of Halealakalā and geographically very close in proximity (populations K (Kanaio) and L (Kanaio–Auwahi)), and one population (N in Makawao–Olinda) is on the north slopes of Halealakalā. These three Maui populations occur at varying elevations (see Table 3). Having at least two very distinct geographic areas on the same island provides the species some redundancy, as a catastrophic event could occur on one side of the volcano impacting one location while preserving the other. However, if the eye of a large category 4 hurricane passed directly over Maui, it could be catastrophic enough to destroy both locations. On Hawaiʻi, one existing wild population (population F, ʻŌʻōkala to Humuʻula) is on the north eastern side of the island on the slopes of Mauna Kea, the other wild population on the slopes of Kohala mountain at the northeastern tip of the island (population I in Honopūʻe), and the two introduced, naturally regenerating populations (populations A (Kīpuka Puaulu) and B (Kīpuka Kī)) are on the southeastern side of the island, on the slopes of Kilauea. These four populations are far enough apart that a catastrophic event occurring near one would not likely impact all, but the two wild populations have very low resiliency. The likelihood of a catastrophic event impacting both Maui and Hawaiʻi is less likely.

Taking into account the resiliency of *Ochrosia haleakalae* populations, having populations on two separate islands may only provide modest benefits in the long-term regarding the species' ability to withstand a catastrophic event. With predominantly small populations with low resiliency, the likelihood of losing one or more populations is high. Although we assess the largest and most resilient of the populations, Kanaio–Auwahi (population L) on Maui, as having moderate resiliency, and the two naturally regenerating, introduced/translocated populations on Hawaiʻi as having low to moderate resiliency, the species has at best moderate redundancy to withstand a catastrophic events. However, because the remaining populations have very low to low resiliency, the species' ability to withstand a catastrophic event and persist into the foreseeable remains uncertain. Because the species range includes two islands, with different geographic areas on each island, but populations with predominantly low resiliency, we assess the redundancy of *O. haleakalae* as low to moderate.

**Representation**

There is currently no data regarding the genetic diversity of *Ochrosia haleakalae*. However, the collection of seeds from various population sites for propagation and outplanting at different population sites (see Conservation Measures and Current Condition) does help maintain genetic diversity. A major obstacle in determining genetic diversity is that the baseline diversity is unknown. Currently, *O. haleakalae* has an estimated seven wild populations (including the naturally regenerated individuals at Kīpuka Puaulu and Kīpuka Kī). Only one of these populations is considered relatively large with natural regeneration, Kanaio–Auwahi (population L) on Maui. Further, this population is augmented with over a thousand outplanted individuals. This population has a high likelihood of having healthy genetic diversity (i.e., diversity of alleles and corresponding traits that benefits the species). Having some connectivity with nearby Kanaio population (K) further contributes to genetic diversity within both of these populations. On Hawaiʻi, Kīpuka Puaulu and Kīpuka Kī (Populations A and B) were first introduced with stock from population L, which may help to maintain genetic diversity for this population, and is considered to be well represented. Both the ʻŌʻōkala to Humuʻula population (F) on Hawaiʻi and Makawao–Olinda (population N) on Maui may retain some genetic diversity, and it is possible that additional individuals are within these areas in difficult to access terrain; however, if regeneration is not occurring due to lack of reproduction or seed predation, this diversity may be decreasing and eventually be lost. The VRPF has been collecting seeds from individuals in Laupāhoehoe and other locations on the slopes of Mt. Kohala for over a decade. Dozens have been outplanted; however, current data suggests only a few have survived. However their collection and propagation efforts helps to preserve genetic diversity for this species. Most of the populations of *O. haleakalae* are extremely small, consisting of only one or a few individuals, which may be limiting genetic diversity for these populations. Propagation and outplanting of this species into existing populations and establishment of new introduced populations should help to preserve remaining genetic diversity within the extant range of the species.

*Ochrosia halaeakalae* is known from dry grasslands and shrublands (Maui) (some of which was previously dry forest), mesic grasslands and shrublands habitat (Maui and Hawaiʻi), wet grasslands and shrublands (Hawaiʻi), mesic forest (Maui and Hawaiʻi), and wet forest (Maui and Hawaiʻi) habitats. Of the seven likely extant populations, three are in mesic forest (two on Hawaiʻi, one on Maui), two are in mesic grasslands and shrublands (one on each island), one in wet forest (Hawaiʻi), and one in dry grassland and shrublands (Maui). Therefore, the species has lost nearly all diversity of any unique traits found in populations located in dry forest and wet grasslands and shrublands, and at risk of losing representation of unique traits from individuals in wet forest habitats.

Further, the addition of two naturally regenerating populations (Kīpuka Puaulu and Kīpuka Kī, populations A and B, respectively) on Hawaiʻi have the potential to expand the geographic and environmental diversity of this species. However, because these two populations are both sourced from population unit L, these populations will not contribute toward genetic diversity for some time, but assist in the preservation of existing genetic diversity found at the source population in Kanaio. Although we do not know the actual genetic diversity of *O. haleakalae* at this time, the fact that the wild individuals are believed to have decreased in population number and size across the species' range since pre-human times, some amount of genetic diversity has probably been lost over time, as well as connectivity. Combining what we know about current population number, resiliency, and distribution (geographic and environmental) across the range of the species, we assess the current representation of this species as low.

## SPECIES VIABILITY SUMMARY

We have assessed the collective resilience of *Ochrosia haleakalae* populations as low, despite the Kanaio–Auwahi population (L) on Maui being assessed as moderate and two other populations assessed as low to moderate. Even if we assign more weight to the wild, augmented, naturally regenerating population in Kanaio-Auwahi due to its importance for the persistence of the species into the foreseeable future, because almost all of the other populations have very low resiliency, we assess the cumulative resiliency of the species as low. We have assessed the species redundancy as low to moderate due to the species having one large wild population on Maui, but otherwise only very small wild populations (i.e., most with fewer than 13 individuals) spread out across Maui and Hawaiʻi. Additionally, we took into account the successful introductions in Hawaiʻi Volcano NP which have resulted in an increase in the species geographic range and therefore redundancy. Similarly, we have assessed the species representation as low, because although the species is distributed across two islands, there are only a handful of individuals or no individuals occupying three of the previous known habitat types. Also, there are only three populations with low to moderate resiliency, two of which are introductions representing the third, so that the more resilient populations, while increasing representation for that source population, do not capture any additional genetic diversity outside of the source population at K (Kanaio). Therefore, the expansion of range for this species into Hawaiʻi Volcano NP increases the representation of the source population, but not enough at the species level to counter the fact that the remaining wild populations are very small, most of which are likely extirpated. Although the species exhibits geographic and ecological diversity, there are not enough resilient connected populations in each habitat type across the species range. Because we assess resiliency and representation as low, and redundancy as low to moderate, we assess the viability of *Ochrosia haleakalae* as low (see Table 5).

Table 5. Viability of Current Condition of *Ochrosia haleakalae*.

| Species Name | Resiliency | Redundancy | Representation | Viability |
|---|---|---|---|---|
| *Ochrosia haleakalae* | Low | Low to Moderate | Low | Low |

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